

CHAPTER 11

Planning for the Future: A Multidisciplinary Approach to Reconstructing the Buag Episode of Mt Pinatubo, Philippines

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INTRODUCTION

Mt Pinatubo, a stratovolcano on Luzon Island in the Philippine archipelago (Figure 11.1), was the site of the greatest volcanic eruption of the 20th century, an event that reduced its height from at 1,745 m to 1,485 m ASL and replaced the summit with a 2.5 km wide caldera, now occupied by a 100 m deep lake.

Within the Philippines, the 1991 eruption and its aftermath caused economic losses estimated at a billion US dollars, and wreaked havoc in the lives of two million people. Part of the reason for the extent of the damage was the lack of knowledge about the past history of Pinatubo eruptions and consequent human responses. By addressing these deficiencies, our interdisciplinary study provides information useful for future hazard reduction. Newhall *et al* (1996) have presented good evidence indicating that Pinatubo's past eruptive episodes have followed a cycle. Centuries of repose are terminated by a powerful, caldera-forming eruption of tephra and pyroclastic flows with large contemporaneous lahars. This phase is followed by a period of post-eruption lahars, with minor eruptions and the filling in of the caldera by dome building. Lahar activity is gradually replaced by the distal deposition of enhanced river sediment loads.

To improve understanding of the cyclic process, we undertook a multidisciplinary study of the so-called Buag episode of Mt Pinatubo's previous eruptions, which lasted from about 800 to 500 years ago. We used geological data and satellite imagery to reconstruct how the

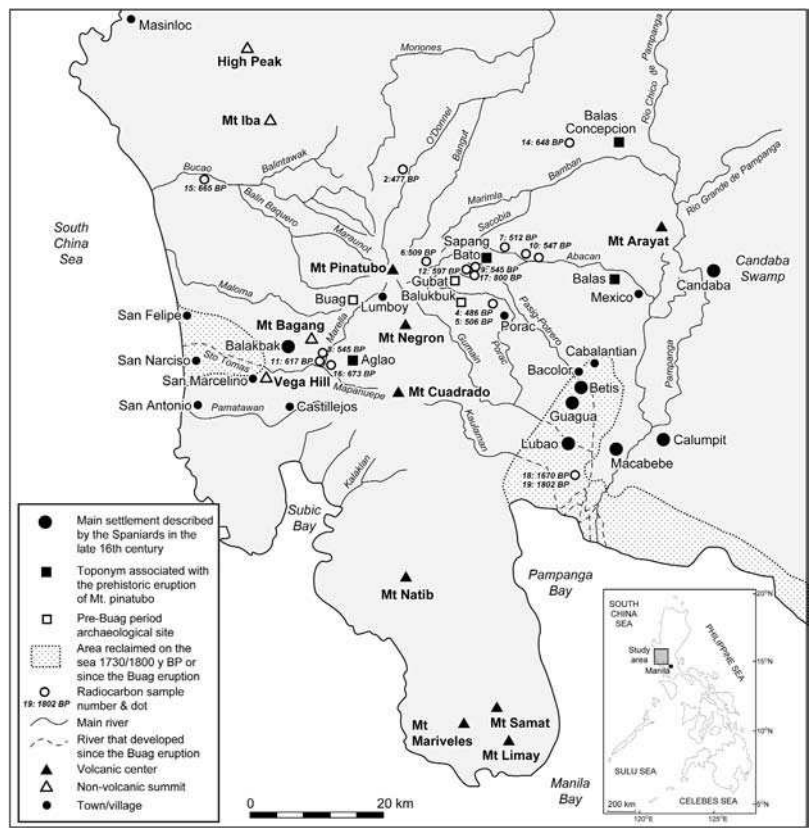


Figure 11.1 Location of the study area showing location of sites, Buag-age radiocarbon samples listed in Table 11.1, and significant changes to coastal topography.

landscape was modified, whilst archaeological and historical data and oral accounts provide an insight into how the eruption and its aftermath affected the people on and around Pinatubo.

BUAG ERUPTION HISTORY

Active volcanism in the vicinity of Pinatubo began at least 1.6 ma and the eruptions that built Pinatubo proper began 1.1 ma or earlier (Delfin 1983, 1984; Delfin *et al* 1996; Newhall *et al* 1996). Since then, the volcano and its surroundings have experienced frequent cataclysmic eruptions of which those of the Buag episode were among the least explosive.

Newhall *et al* (1996) have named the most recent prehistoric eruption period after Buag, a village of San Marcelino, Zambales in the Marella River valley. Charcoal and wood from lahar and fluvial deposits suggest

that the Buag eruptive period begun as early as 600 or even 800 BP (Table 11.1 and Figure 11.1). Debris from eruptions of the Buag period buried all the major watersheds of the volcano, except those of the Gumain and Porac rivers. The composition and distribution of these deposits indicate a Plinian-type eruption that produces avertical eruption columns spreading tephra far and wide and numerous smaller pyroclastic flows. This Plinian eruption probably left a caldera comparable in size to that produced in 1991, but the depression was filled and overtopped when glassy andesite lavas of the last Buag eruptions built up Pinatubo's steep-sided, 2 km wide, pre-1991 summit dome.

The topography of Mt Pinatubo prior to the 1991 eruption also hints at the nature and sequence of events associated with the Buag eruption. Commanding the terrain in Figure 11.2, the dome is marked by a prominent summit hill with its north-eastern side apparently breached by a short lava flow. This dome partly filled the large caldera that existed before the dome-forming events, leaving only a circular trend of discontinuous ridges to mark the rim of the former caldera. Further down the western flanks, the topography displays large pyroclastic fans deposited during the Buag event, in the same areas reached by the 1991 pyroclastic flows and filling the valleys in a similar manner. Smaller pyroclastic fans were created on the northern and south-eastern sections of the volcano. Before the 1991 eruption, the pyroclastic fans had been deeply incised with river valleys, just as the recent deposits continue to be dissected.

LAHARIC AFTERMATHS

Each major plinian Pinatubo eruption overloaded the watersheds on the volcano with great volumes of pyroclastic materials, thereby initiating a period of accelerated sedimentation (Major *et al* 1996; Newhall *et al* 1996; Pierson *et al* 1992; Pierson *et al* 1996; Rodolfo *et al* 1996; Scott *et al* 1996; Umbal and Rodolfo 1996). These periods of rapid aggradation by lahars, which lasted for several years or decades after each main eruptive phase, built up and laterally expanded the alluvial fan systems that drape the footslopes of Mt Pinatubo. Streams draining the watersheds outside the volcano were less affected by pyroclastic deposition. Where these were tributaries of a lahar-aggrading river, they would often be dammed by lahar sediments and transformed into ephemeral ponds or longer lasting lakes. Failures of such natural dams cause dangerous lake-breakout floods that pose a significant downstream hazard (Rodolfo *et al* 1996; Umbal 1994; Umbal and Rodolfo 1996). Over millennia, fluvial processes have transported the debris from all the major eruptions downslope, building deltaic coastal plains and pushing the shores seawards.

Table 11.1 Radiocarbon data of the Buag eruptive event (modified from Newhall *et al* 1996). C^{14} ages have been defined using the Libby half life of 5,568 years. Calibration ages have been calculated by use of calibration curves developed by Stuiver and Reimer (1993). The calibrated ages are the statistically most-likely equivalent in calendar years before 1950 (BP) using 1-sigma range. Sample locations are shown in Figure 11.2. (Note: *samples from Newhall *et al* 1996; **new data)

Lab. Number	Latitude ($^{\circ}$ N)	Longitude ($^{\circ}$ E)	Material	Occurrence	Drainage	C^{14} Age (BP)	Calibrated Age (BP)	Significance
WW-111*	15 $^{\circ}$ 04	120 $^{\circ}$ 16	Charcoal	Cultural layer	Marella	397 $\pm$ 70	476	Dates latest occupation; settlement on old lahar deposits.
WW-26*	15 $^{\circ}$ 16.8'	120 $^{\circ}$ 22.7'	Wood	Fluvial deposit	O'Donnell	400 $\pm$ 80	477	Latest major filling of Crow Valley.
W-6478*	15 $^{\circ}$ 09.2'	120 $^{\circ}$ 34.4'	Wood	Soil above gravel	Abacan	410 $\pm$ 55	485	After high-energy stream; before latest pre-1991 lahars.
WW-4684	15 $^{\circ}$ 05.4'	120 $^{\circ}$ 31.5'	Charcoal	Cultural layer	Porac	415 $\pm$ 40	486	Dates latest occupation.
WW-4683**	15 $^{\circ}$ 05.4'	120 $^{\circ}$ 31.5'	Charcoal	Cultural layer	Porac	455 $\pm$ 40	506	Dates latest occupation.
W-6314*	15 $^{\circ}$ 09'	Ca 120 $^{\circ}$ 24'	Charcoal	Pyroclastic-flow deposit	Upper Sacobia	460 $\pm$ 30	509	Youngest pre-1991 pyroclastic flow in Sacobia.
Beta*	15 $^{\circ}$ 10.5'	120 $^{\circ}$ 29.5'	Wood	Post-pyroclastic-flow soil	Abacan	470 $\pm$ 50	512	Start of latest pre-1991 fluvial deposition in Abacan.
W-6509*	14 $^{\circ}$ 59.9'	120 $^{\circ}$ 15.5'	Charcoal	Lahar deposit	Marella	560 $\pm$ 60	545	Covered by 1992 lahars.

WW-25*	15°8.2'	120°28.8'	Wood	Lacustrine deposit	Pasig-Potrero	560 ± 70	545	Latest fill in the north fork, Pasig-Potrero.
WW-21*	15°09.7'	120°33.4'	Charcoal	Silt over lahar deposit	Abacan	570 ± 70	547	Age of terrace by Friendship Bridge, south edge, Clark Air Base.
WW-6505*	14°59.9'	120°15.6'	Charcoal	Lahar deposits	Marella	600 ± 60	617	Covered by 1992 lahars.
WW-29*	15°08.2'	120°28.7'	<i>In situ</i> root	Fluvial deposits	Pasig-Potrero	630 ± 70	597	After latest pre-1991 downcutting; before major siltation.
Ebasco*	15°03.3'	120°17.0'	Wood	Lahar deposits	Marella	635 ± 80	593	Lahar just below toe of morphologically youngest pre-1991 pyroclastic-flow deposit.
WW-28*	15°18.5'	120°35.7'	Wood	Flood-plain deposit	Bamban	660 ± 80	648	Sedimentation across broad Bamban-Capas flood plain.
WW-107*	15°16.03'	120°05.3'	Charcoal	Hyper-concentrated flow deposit	Bucao	730 ± 80	665	Latest major sedimentation in Bucao; overtopped in 1993.
WW-6504*	14°59.9'	120°16.6'	Charcoal	Fluvial deposits	Marella	760 ± 60	673	Covered by 1993 lahars.
WW-31*	15°08'	120°29'	Wood	Lahar deposits	Pasig-Potrero	950 ± 70	800	

(continued)

Table 11.1 (Continued)

<i>Lab. Number</i>	<i>Latitude (°N)</i>	<i>Longitude (°E)</i>	<i>Material</i>	<i>Occurrence</i>	<i>Drainage</i>	<i>C¹⁴ Age (BP)</i>	<i>Calibrated Age (BP)</i>	<i>Significance</i>
WW-4686**	14°52.008'	120°32.090'	Wood	Flood-plain deposit	Guagua-Pasac	1730 ± 40	1670	Reworked? Wood fragments in Buag age deposit or undocumented pre-Buag event.
WW-4685**	14°52.008'	120°32.090'	Wood	Flood-plain deposit	Guagua-Pasac	1800 ± 40	1802	Reworked? Wood fragments in Buag age deposit or undocumented pre-Buag event.

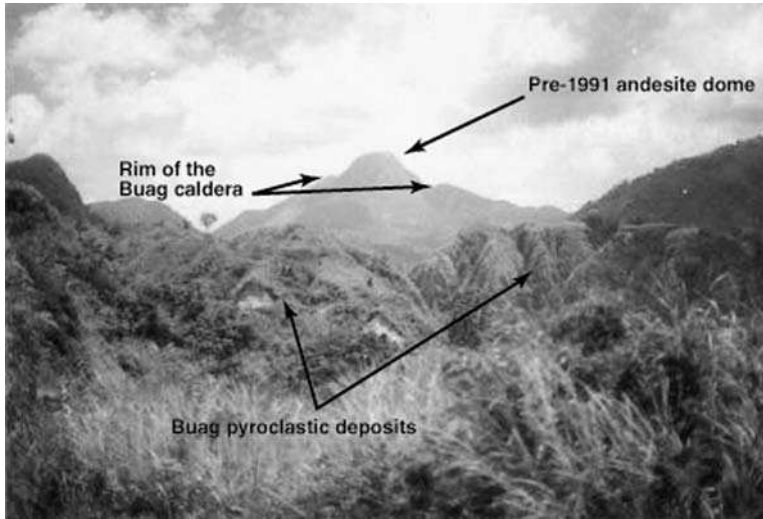


Figure 11.2 View of the east side of Mt Pinatubo in 1990 (photograph by Luminoso H. Dizon).

Lahars of the Buag eruptive period were no exception. They were mostly confined within the kilometre-wide channel banks of major rivers. At the Marella-Mapanuepe river confluence, lahars were built up slightly higher than the 120 m elevation, suggesting that a lake similar in size and shape to the present-day Mapanuepe Lake was formed; however, the lake had ceased to exist even before the Spaniards explored Zambales in the 16th century.

The lahars created during and after the 1991 eruption have had very similar patterns and channel routes as those of the Buag period; however, they rapidly filled channels and overflowed to inundate adjacent alluvial plains that the Buag lahars had not been affected (Umbal 1997). This may be because the repose interval between the 1991 and last Buag eruption was too short to allow the drainages to fully adjust to the influx of Buag sediment before the 1991 debris arrived.

MAJOR ENVIRONMENTAL CONSEQUENCES

The huge lahar events of the prehistoric eruptions of Mt Pinatubo shaped the surrounding environment in major ways. At the mouths of the Pampanga and Santo Tomas rivers, respectively east and west of the volcano, lahars infilled shallow coastal bays. The process has been reconstructed by identifying old beach ridges that appear as lighter toned linear features in both aerial photographs and in 1991 synthetic aperture radar images of the coastal areas (Figure 11.3). To verify and



Figure 11.3 Landsat TM satellite image (19 February 1995) of the southern part of the Central Luzon Basin with the tentative alignment of the paleo-shoreline on the northern edge of the Manila Bay. The paleo-shoreline was delineated after the current limit of the wetlands and core data.

evaluate the old environments on the ground, sediment cores up to 10 m long were acquired in the Pampanga delta plain and logged according to differences in colour, grain size, gross composition, and sedimentary structures (Figure 11.4).

Filling of Pampanga Bay

Beach ridges along the north-east coast of Manila Bay diverge north-westward. In the Bulacan River area, the oldest and most landward ridge is situated 7 km north of the present shoreline. Exactly when these paleo-shoreline positions were occupied has not yet been established.

An area of roughly 360 km² has supposedly been reclaimed from the sea. Given an average sea depth of 3–4 m, this suggests a sediment volume of 1.1–1.4 km³ is required to fill the paleo-Pampanga Bay. The volume of pyroclastic materials deposited in the watersheds of the Pasig-Potrero, Abacan, Sacobia, and Bamban rivers that empty into Manila Bay during the 1991 eruption has been estimated at 1.0–1.6 km³ by Pierson *et al* (1992). These data indicate that a 1991 size-like eruption – like the Buag event – may be sufficient to fill the paleo-Pampanga Bay.

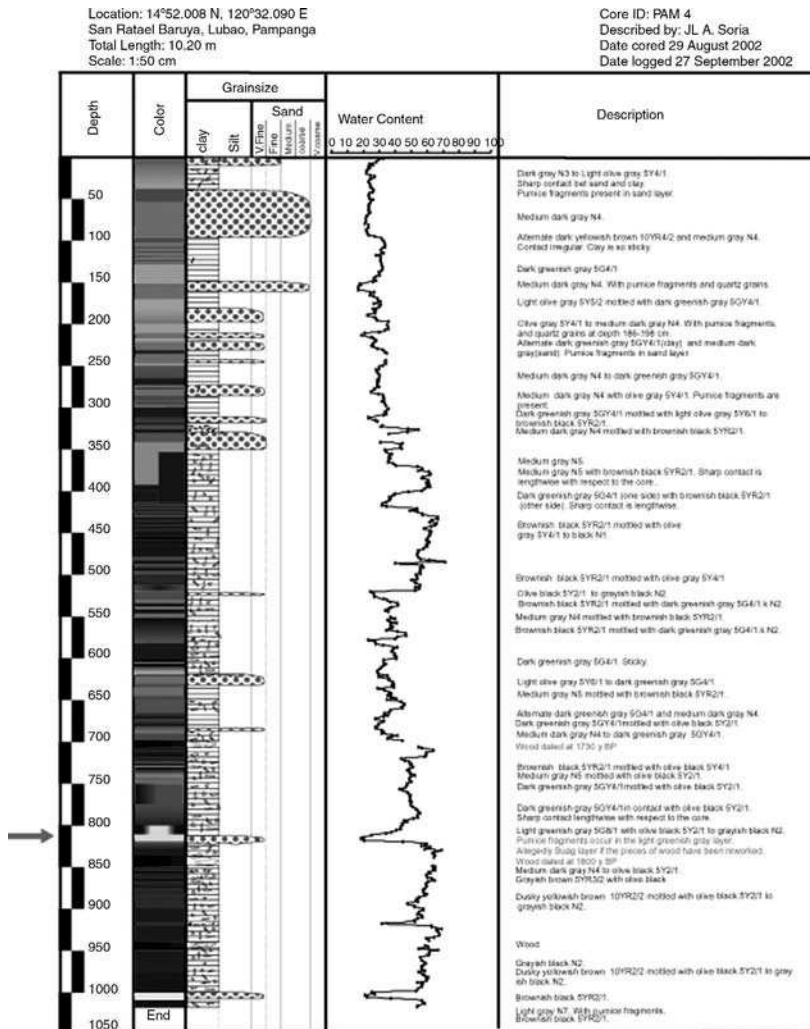


Figure 11.4 Log of the 10m push core in San Rafael Baruya, Lubao, Pampanga.

The San Rafael core data suggest that the shoreline once followed the general present-day landward limit of the wetlands (Figure 11.1). Either around 1.73–1.8 ka or soon after the start of the Buag event, the ancient Pampanga Bay may have begun to be filled, thereby forming this low-lying and virtually flat part of the delta plain and cause the shoreline to regress. This may be reflected in the toponym of the town of Guagua around 15 km inland from the current shoreline. Guagua is a corruption of *'Ulaud'*, meaning 'river mouth', indicating a former coastal location.

Moreover, the name of the town of Lubao, also 12 km from the shore, refers to a floating community.

Evolution of the Zambales Coastal Plain

Siringan and Ringor (1996, 1997) used synthetic-aperture radar satellite images and aerial photographs to trace beach ridges along the southern coastal plain of Zambales. At the mouth of the Pamatawan River, which has no delta at present, they reconstructed a paleo-delta that could have existed approximately 1 km seawards of the present shoreline. They hypothesised that this paleo-delta was formed when Buag eruptions enhanced the Pamatawan sediment load. The return of the sediment load of the Pamatawan River to pre-Buag eruption levels may have led to its eventual erosion. Presently, the Pamatawan River has no delta because dikes now constrain Pinatubo sediment within the Santo Tomas River channel.

Similar phenomena may have occurred at the mouth of the Bucao River. According to anecdotal accounts, the Bucao River mouth was formally an estuary in which barges or galleons docked during the Spanish era and up to the early 1900s. Even by 1680, the writings of the Spanish friar Domingo Pérez indicate that relatively recent major lahars had left unconsolidated, still unvegetated debris on the Bucao plain:

sandy ground which is very large and full of rocks left by the river which flows from the mountain of Pinatuba [*sic*]; and in those places where there are no rocks, but only the sand, the road is also very wearisome because the sand has no cohesion, and the least wind that blows lifts the dust. (Blair and Robertson 1903–09, vol 47: 296)

SOCIOECONOMIC CONSEQUENCES

Such large eruptions and their environmental consequences must have seriously disturbed the socioeconomic milieu. Archaeological excavations in both Pampanga and Zambales provinces, respectively on the eastern and western slopes of Mt Pinatubo, have unearthed evidence that prehistoric economic activities and settlement patterns were dislocated following the Buag eruptions.

Evidence of pre-Buag human habitation was uncovered in Babo Balukbuk, Porac, Pampanga, on the western bank of the Porac River (Figure 11.1). This area has been the focus of archaeological research since the 1930s (Beyer 1947; Fox 1960a, 1960b). Recent excavations of a 32 × 40 m site called Dizon-1 unearthed 22,721 artefacts, including locally made earthenware potteries, Chinese and Vietnamese ceramic shards, bronze rings, and iron implements (de la Torre 1999; Dizon 2002; Paz 2003).

A stratigraphic sequence of at least four cultural horizons has been distinguished at Babo Balukbuk (Figure 11.5). Pottery recovered from a 4 m deep trench documents human presence before 2.3 ka, but it is unclear if this habitation was a settlement. The Maraunot eruptive period, starting around 2.3 ka, covered the area with pyroclastic-flow deposits more than 3 m thick on which, some time during the 13th century, a settlement was established by people who grew rice, built sturdy structures, used metal implements, traded for earthenware vessels, and may have also made their own pottery and stoneware. They wore glass beads and metal bangles and they buried their dead with tradeware ceramics near their houses.

It is not known if this site was abandoned because of early Buag eruptions, but the absence of volcanic deposits on the top of this cultural layer does not exclude the possibility that the people fled from volcanic activity. Later, habitation and burial areas were replaced by ploughed fields for rice agriculture that disrupted the surface on top of 13th–14th-century burials. This indicates a discontinuity of settlement and the arrival around 200 years later of a different group of rice farmers who also interred their dead with tradeware ceramics among their houses. Another possible explanation is that the time lapse of over a century was sufficient for a community to have lost lineage ties with or forgotten the existence of the previous community.

The last Buag eruption to leave deposits at Babo Balukbuk covered the fields with airborne tephra (<1 m thick deposit), which buried pottery vessels and other artefacts lying on the land surface. Recent radiocarbon dating of charcoal samples recovered from inside a buried hearth yielded mean calibrated ages of 506 (WW-4683) and 486 BP (WW-4684) (Table 11.1 and Figure 11.1). These dates are consistent with the age of the latest tradeware ceramics recovered from this area (early 16th century) and the age from latest occupation of the Buag site on the western flank of the volcano. This area was not recultivated until the early 20th century. The 1991 Pinatubo eruption left a new layer of light-coloured sandy tephra, around 10 cm thick, but the land continues to be dedicated to agriculture, mostly for sugarcane and cassava.

Inland, near Mt Bagang on the north bank of the upper Marella River (Figure 11.1), systematic archaeological surveys and excavations were conducted in 1990 in the San Marcelino settlements of Buag, Manggahan, and Kakilingan, around 10 km south-west of the pre-1991 Pinatubo summit (Dizon 1990). The pre-1991 stratigraphy of the sites provides the following historical reconstruction (Figure 11.6).

People who used earthenware and stoneware pottery established a settlement, marked by two successive cultural layers, on several metres of sterile ash and pumice deposits from a probable pre-Buag lahar or

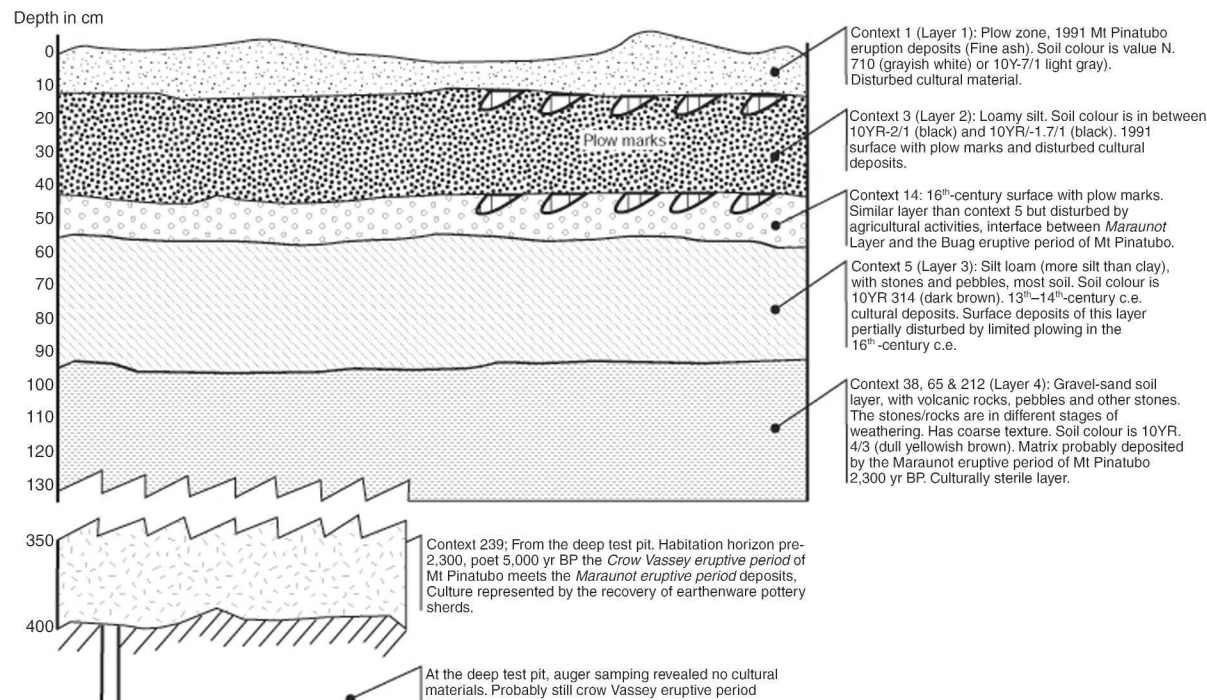


Figure 11.5 Composite stratigraphic profile of the Balukbuk archaeological site in Porac, Pampanga.

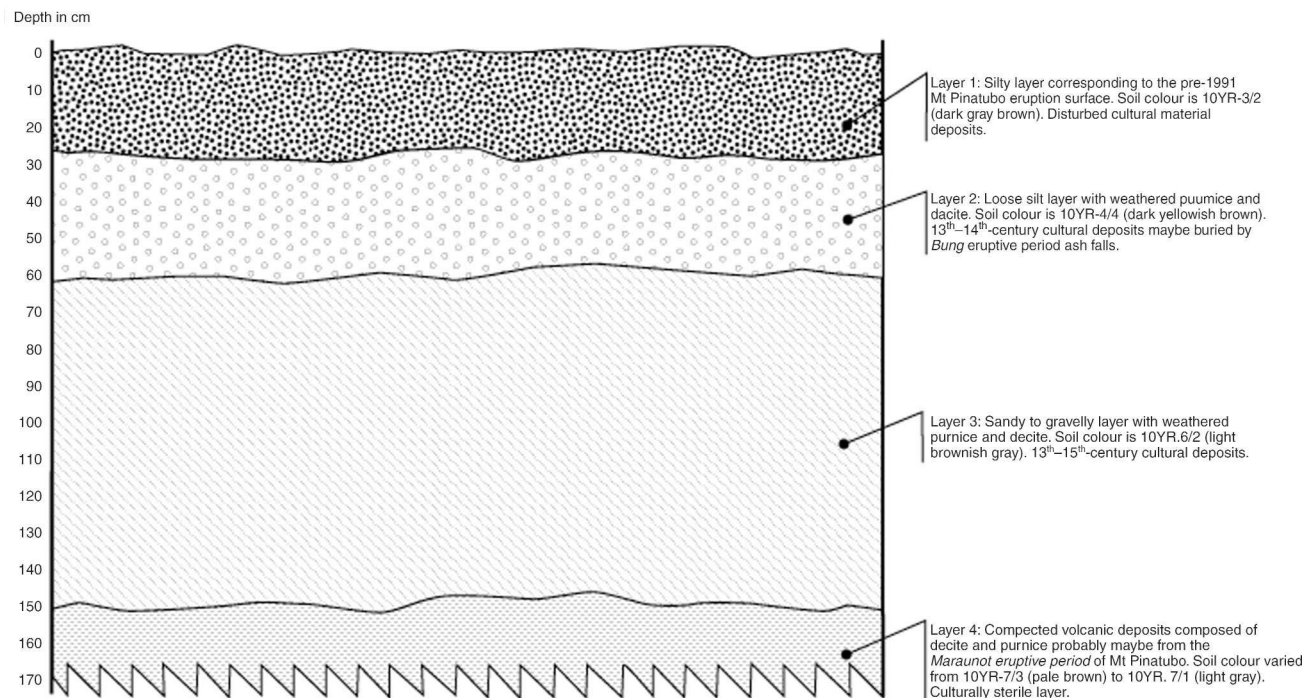


Figure 11.6 Composite stratigraphic profile of the Buag archaeological site in San Marcelino, Zambales.

pyroclastic flow (Newhall *et al* 1996). Chinese and other Southeast Asian ceramic tradeware show that this site was occupied at least from 1250–1450 AD. Smelting slag and metal implements demonstrate that the people worked metals, and rice husks within a whole pot indicate that they consumed rice and may have tilled it themselves. Congruence of geological and archaeological records around the mid-15th century suggests that this settlement was abandoned during the last Buag eruption. The ashy, pumice-bearing soils that contained the artefacts indicate that this settlement was lightly buried by a few decimetres of tephra. In 1990, these two cultural layers were overlain by a contemporary ploughed agricultural layer of dark brown loam soils containing remains of root crops. The 1991 Mt Pinatubo eruption added 30 cm of tephra on the top of this layer.

Chinese and Southeast Asian trade ceramics from excavations on both the eastern and western slopes of the volcano indicate that from the 13th to some time between the late 15th and early 16th centuries AD, both the Buag and Babo Balukbuk sites were occupied; Buag would have been easy to reach from the San Marcelino coast. At the time, the interior areas of central Zambales may have been accessible by small boats following river systems from the coastline between San Narciso and San Antonio. Upstream, this would have been eased by the possible existence of a lake along the Mapanuepe River, as suggested by the geological records. Chinese Ming Dynasty annals mention different place names that may have been located near Mt Pinatubo. According to Wang (1964), Li-Gun-Tiong-Pang may have been a trading post situated near the present town of San Narciso. Ming annals also cite a 'very high mountain' called Piao San or Pio San in the Zambales Mountains that may have been Mt Pinatubo. No archaeological remains have yet been excavated from the paleo-shores of the Pampanga Bay, but this does not exclude the possibility that this area was another trading port for Southeast Asian traders in prehistoric times, where artefacts that eventually reached Porac landed.

The last Buag eruptions appear to have disrupted these commercial activities, burying or forcing abandonment of villages and trading markets such as the Buag and Babo Balukbuk settlements. Possible infilling of the Santo Tomas and Pampanga estuaries also would have eliminated the inland anchorages of merchant ships. Moreover, Mapanuepe Lake, which previously may have facilitated the upstream incursion of boats, disappeared following the Buag eruption, as suggested by the historical record (Wang 1964) and the lack of mention of the lake in the early Spanish accounts. New pyroclastic deposits on the flanks of the volcano would have disrupted travel and trade for years.

POPULATION REDISTRIBUTION

The population occupying the region around Mt Pinatubo at the time of the Buag eruption probably differed greatly from that encountered by the Spanish conquistadors led by Martín de Goiti in 1571. This may have been particularly true on the eastern side of the volcano. The Spaniards described many densely populated riverbanks in the Pampanga River delta, within a triangle extending from Macabebe and Lubao to Betis or Vitis, now part of Guagua (Blair and Robertson 1903–09; de San Agustín 1998). Some fortified settlements were quite large, notably Betis (7,000) and Macabebe (2,600) (Jocano 1975). If this area had been reclaimed by pre-Buag or Buag lahars, these settlements must have been established well before the Spaniards arrived but after the last Buag eruptions that affected the south-east sector of the volcano.

The Buag eruptions must have drastically redistributed any population southwards away from the volcano. Indeed, Spanish chroniclers reported at the end of the 16th century that populations near Mt Pinatubo were very sparse. Some local place names in this upper region, however, may reflect oral memory of the Buag eruption. The three main lahar channels of the east side of the volcano are the Pasig-Potrero, Abacan, and Sacobia rivers, respectively in the municipalities of Bacolor and Mexico in Pampanga and Concepción in Tarlac. Each of these towns has villages named Balas, which means ‘sand’ in Kapampangan. This might suggest that these communities had been affected by lahar onslaughts. The name of Sapang Bato village in Angeles City literally means ‘the river of stones’, possibly referring to the coarse material transported down the Abacan River by lahars.

A somewhat similar, but more eastern, redistribution of the population also occurred after the 1991 eruption, because southern Pampanga experienced heavy flooding. The municipalities of the eastern half of Pampanga have indeed displayed the highest rates of population increase between 1990 and 2000 (Gaillard 2002). If the lahar threat may have guided the population towards safer grounds, the resettlement policy of the government definitely played a great role in this redistribution.

South-west of Mt Pinatubo, the plain of the Santo Tomas River is one of the few large agriculture flatlands in Zambales province. The towns of San Antonio, San Narciso, San Marcelino, San Felipe, Casillejos on the plain, together with most of their villages, have Spanish names. This is because Castillejos, the oldest town was settled by Tagalogs from Subic Bay in 1743, and those bearing the names of saints were settled by Ilokanos from the north who followed the coast of the South China Sea to migrate there in the mid-19th century, more than two centuries into the Spanish colonial period (Apostol 1956; De Jesus 1990).

One reason why the plain remained unsettled for so long is because the Sambals along the coast were fierce, and the Aytas of the surrounding mountains were 'the cruelest of that scattered nation'; in 1648, they killed Fray Pedro de Valenzuela and took his head (Pérez 1680 in Blair and Robertson 1903–09, vol 37: 170). Even an 18th-century history (De Santa Teresa 1743 in Blair and Robertson 1903–09, vol 36: 174) refers to the 'great risk' posed by Aytas in revolt.

The eruptive history may also have played a role in the settlement of the Santa Thomas River region. First, the prehistoric Santo Tomas lahars were destructive enough to bury or discourage all human settlements. Second, the Santo Tomas plain formerly was a bay of the South China Sea that was filled up by Buag lahars not too long before the Spaniards arrived. The absence of settlements on the Santo Tomas plain soon after the Buag eruptive period is consistent with the 17th-century Spanish chronicles, which state that the people of this area lived only in the mountains and the Spaniards had a hard time making them resettle in the lowlands (Scott 1986). This would also indicate that on the western side of Mt Pinatubo, unlike on the eastern side, the Buag eruptions had little effect on the population, which remained concentrated on the volcano flanks.

ORAL TRADITIONS

During the Buag eruption period, the slopes and surroundings of Mt Pinatubo were probably inhabited by three major ethnolinguistic groups. On the east side, the Kapampangans occupied the south-western part of the Luzon central plain. Early Spanish accounts suggest that the narrow coastal plain of Zambales, and possibly also inland Pampanga were inhabited by Sambals (Blair and Robertson 1903–09), which are nowadays divided into Sambal Tina and Sambal Botolan. Finally, the Aytas inhabited the east and west flanks of the volcano. These three groups preserve traces of the prehistoric eruption in their local legends.

The toponym Pinatubo itself, literally 'made to grow' in the Sambal language, implies that people may have witnessed the growth of the dome that followed the eruption. The Aytas oral tradition best describes what could have been a prehistoric eruption (Rodríguez 1918). In this legend, two supernatural beings called Blit and Aglao fight a mischievous turtle. The most realistic part describes the eruption as follows:

Finding the lake a useless place of refuge, he climbed the Mount Pinatubo in exactly twenty-one tremendous leaps. When he had reached the top, he at once began to dig a big hole into the mountain. Big pieces of rock, mud, dust, and other things began to fall in showers all around the mountain. During all the while, he howled and howled so loudly

that the earth shook under the foot of Blit, Aglao, and his hosts. The fire that escaped from his mouth became so thick and so hot that the pursuing party had to run. (Rodríguez 1918)

This description evokes all the destructive, frightening phenomena experienced during the 1991 eruption: falling rock debris, mud, dusty tephra, noise, and sustained earthquakes. Once the eruption stopped, a great hole is said to have replaced the former summit of the mountain and a lake with clear water had been filled with rocks and mud. The geological evidence indicate that this lake may have been located along the Mapanuepe River, an idea reinforced by the toponym Aglao of a village that was drowned in 1991 when lahars descending the volcano along the Marella River dammed the Mapanuepe River to form a lake.

A few other authors have also referred to behaviour that could be viewed as traces of oral memory among the Ayta people. Speaking about hunting practices, John Garvan (1963: 72) recalled that jesting remarks about the quarry irritate the spirits of Mt 'Pinyatubu' and may cause petrification. Rodolfo (1995: 88) reported that Ayta parents would warn children who will not go to sleep by saying '*Apo Namalyari* will wake up and start throwing stones if you don't behave'.

Among the Kapampangan community that occupies the eastern foothills of the volcano, blurred traces of a prehistoric eruption appear in a couple of legends, transmitted from one generation to another. In all the versions of the different legends, Mt Pinatubo and Mt Arayat, sometimes referred to as giants or brothers, fight by throwing boulders at each other. One of the missiles supposedly decapitates Mt Arayat, forever destroying its perfect conical shape. The war lasted for a few days before calm is restored for several centuries (Castillo 1918; David 1918; Galang 1940; Hilario-Lacson 1984; Nicdao 1918a, 1918b; Quizon 1918). The boulders spewed out by Mt Pinatubo could refer to volcanic blocks. It is also noteworthy that the Kapampangan people named Mt Pinatubo '*Apung Punsalan*', literally the 'lord of enmity', possibly referring to past and destructive eruptions of the volcano.

More puzzling are the words '*silakbu*' and '*margaha*' in the lexicon of the village of Cabalantian, in the Pampanga municipality of Bacolor. According to Forman (1971), '*silakbu*' stands for 'volcanic eruption', whereas '*margaha*' means 'volcanic ash' and in rare cases 'lava'. This last term is not Kapampangan because there is no letter 'H' in this language. '*Margaha*', however, is a word used by the Bukidnon indigenous group that inhabits the flanks of Mt Kanlaon, an active volcano on Negros island in the central Philippines, where it designates the old crater. It is difficult to understand how the word reached the Mt Pinatubo area. Spanish friar D Bergaño (1732) further provides a translation for the word 'volcano' or '*sibul*' (which also means 'source' in the Kapampangan language).

The Sambal Tina ethnolinguistic group may preserve a memory of the eruption in its local folklore. A local story recorded by Santos (1979: 258) says that a mountain rose from the place where a magician planted a stone as if it was a seed. But 'the magician neglected to check the rapid growth of the Pinatubo (planted) mountain that grew to such proportion that it destroyed the regions surrounding it. The whole plain was soon covered with rocky outcroppings.'

THREE PHASE SYNTHESIS

Bringing the geological, geomorphic, archaeological, and oral records together, we suggest the Buag eruptive period of Mt Pinatubo can be divided into three phases, as synthesised in Table 11.2. First, an initial Plinian eruption generated widespread tephra falls and accompanying pyroclastic flows and lahars close to the volcano; next came the extrusion and growth of a dome; and, finally, the collapse of part of the growing dome generated the youngest, distinctive ash flow sheet filling the Marella valley. The lahars of the second phase gradually became the more normal, rain-induced sedimentation that continued through and beyond the third phase, slowly filling in the shallow bays in Pampanga and Zambales. On a geologic time scale, all three phases can be treated as contemporaneous, but the opening Plinian eruption may have preceded the second and third phases by years, decades, or even centuries.

Had the main caldera-forming Buag eruptions happened only at 500 BP, it is surprising that the Spaniards, who arrived in Pampanga and conquered it only a few generations later in 1571, did not hear about such cataclysmic events from inhabitants of the many large, well-settled towns there. Either the eruptions occurred so long ago that they were lost to memory or the people the Spaniards encountered had settled the delta region and Manila after the major eruptions. People in the Papua New Guinea highlands have a strong oral tradition about the Long Island eruption that occurred more than three centuries ago (Blong 1982), and inhabitants of Mt Parker in Mindanao have a sketchy oral history of its 1641 eruption (Delfin *et al* 1997). This reinforces the radiocarbon dates that indicate main plinian eruptions of the Buag period occurred significantly earlier than the ca 500 BP pyroclastic deposits at the Buag-type locality.

The best temporally constrained event is in the south-west sector of Mt Pinatubo. Here the emplacement of the 'Lumboy ash flow sheet' apparently forced settlers to abandon the lower Marella valley and provided the sediment for the final filling of the Pamatawan and Santo Tomas river valleys. At least two dates from the Marella valley, one from the Buag archaeological site and one farther downstream, suggest

calibrated calendar dates ranging from 476–545 cal BP (WW-111 and W-6509) (Table 11.1 and Figure 11.1). This would put the event sometime in the early-to-mid-15th century, which is consistent with the ages of Chinese and Anamese ceramics found at Buag. The destruction of the old Buag settlement following the partial collapse of the dome may also be retained in the toponym Buag, which means ‘to collapse over’ or ‘to pull over’ in local languages.

If the final aggradation above sea level of the pre-1991 Santo Tomas and Pamatawan river valleys were consequences of this event, then it is indeed likely that around 500 BP, a shallow embayment of the South China Sea separated what are now the towns of San Felipe in the north and San Antonio and Castillejos in the south. Such an embayment would have allowed Chinese or Anamese trading junks to penetrate further eastwards, closer to the Pinatubo foothills. This is supported by reference to trading in this area within Chinese Ming Dynasty annals. Old lahar deposits at the confluence of the Marella and Mapanuepe rivers, together with the Ayta myth on the origin of Mt Pinatubo, suggest that a lake occupied the present location of the Mapanuepe Lake before the 500 BP eruption, which no longer existed when the Spaniards arrived in the late 16th century.

The early Plinian phase of the Buag period that showered tephra over a wide area and formed a caldera is well retained in both oral history and toponymy. The best account is the Ayta legend about how the supernatural spirits Blit and Aglao fought a turtle that scaled the summit, dug a hole, howled loudly and breathed fire, shaking the earth. In Bacolor, Mexico, and Concepción, villages named Balas, which means ‘sand’ in Kapampangan, indicate memories of lahars or pyroclastic flows. That the Porac river valley was not inundated by a major pyroclastic flow during is consistent with the tephra fall recorded in the Babo Balukbuk archaeological site. Despite the uncertainty regarding the wood samples recently dated at 1670–1802 BP (samples WW-4685 and WW-4686) (Table 11.1 and Figure 11.1), the Lubao-Bacolor area very likely was a shallow northward extension of Manila Bay until filled in with pre-Buag or early Buag-period sediment. This is further indicated by the toponym Uaua, meaning ‘river mouth’, 15 km inland from the current shore.

Finally, the Buag eruptions would have triggered a general redistribution of the population from the foothills of the volcano towards the delta plains if this had been reclaimed downstream by lahar deposition. This is underlined by the toponymic records on the eastern side of Mt Pinatubo, and the early Spanish chronicles in the late 16th century. Oral accounts also confirm that the Pinatubo environs at the time of the Buag eruptive period were predominantly inhabited by three ethnolinguistic groups, the Aytas, Kapampangans, and Sambals.

Table 11.2 Compilation of geological, geomorphic, archaeological, and oral records of the 2,300 y BP Maraunot and 500 y BP Buag eruptions of Mt Pinatubo

<i>Eruptive Period</i>	<i>Mt Pinatubo Geology</i>	<i>Sedimentological-Geomorphic Records</i>	<i>Lahar Records</i>	<i>Archaeological-Cultural Evidence</i>	<i>Geographic Toponymy and Oral and Historical Records</i>
Buag (~800–500 y BP)	Dome-collapse generated 'Lumboy ash flow sheet' in Marella River valley.	Sediment loading of Pamatawan River and consequent filling of Pamatawan River paleo-delta (San Marcelino–Castillejos flood plain).	C ¹⁴ dating indicates that lahar deposits comprising the upper layers of the Pamatawan Plain are from the 2,500-year-old Maraunot eruption period; the in-channel terraces along the Santo Tomas River date back to the Buag eruptive period.	Buag site reveals Chinese ceramics from mid-Ming Dynasty, and Anamese ceramics from 14 th –16 th century.	Several alleged mentions in the Ming Annals of trading posts and other land marks along the shore of the Santo Tomas Bay or in the Zambales Mountains. Village named 'Buag', meaning 'to pile over', buried by the collapse of the dome. Towns with Spanish names in the Santo Tomas valley were settled only in the 18 th and 19 th centuries. Town named Uaua ('mouth of the river') 15 km inland indicates seaward displacement of the shoreline following the Buag eruptions.

	Extrusion and growth of Pinatubo dome, probably filling or destroying the summit caldera.				'Pinatubo' name suggests that dome growth was witnessed by Ayta people.
	Caldera-forming Plinian eruption with related pyroclastic flows and lahars in major watersheds (except Gumain and Porac).	2 cm light olive grey fine-grained ash layer of marine environment; 8 m from surface in Baruya, Lubao. Wood samples from immediately below and above the ashy layer dated at 1,800 and 1,730 y BP.	500-year-old lake deposits indicate the occurrence of a lake upstream of Mapanuepe River during the Buag-period eruptions. Absence of a lake before the 1991 eruption and from historical records suggest that it was filled or drained before the Spanish explorations.	Babo Balukubuk site (Porac) with Chinese and Anamese ceramic shards suggestive of 13 th –16 th -century human occupation. Charcoal samples recovered inside a buried hearth yielded ages dated at 506 and 486 y BP.	Ayta legend of supernatural spirits Blit and Aglao fighting a turtle that scaled the summit, dug a hole, howled loudly, and, breathing with fire, shook the earth. Villages named Balas (sand in Kapampangan) in Bacolor, Mexico, and Concepción suggest memory of lahars or pyroclastic-affected lands.
Maraunot (3,900?–2,300 y BP)	Pyroclastic flows, lahars, and streamflows.	Areas of the highest relief on the plain and alluvial fan of the Pasig-Potrero and Santo Tomas rivers are underlain by Inararo deposits.	C ¹⁴ dates indicating that the uppermost layers of the Pamatawan Plain comprise 2,500-year-old Maraunot-period lahars. Possible alignment of the Marella-Santo Tomas with the Pamatawan River.	Babo Balukubuk site (Porac) revealed pottery in layer of Maraunot eruptive period.	

(continued)

Table 11.2 (Continued)

<i>Eruptive Period</i>	<i>Mt Pinatubo Geology</i>	<i>Sedimentological- Geomorphic Records</i>	<i>Lahar Records</i>	<i>Archaeological- Cultural Evidence</i>	<i>Geographic Toponymy and Oral and Historical Records</i>
	Widespread distribution of pyroclastic-flow and lahar deposits.	Pre-1991 eruption channels of most of the major drainages and final configuration of their watershed areas were probably developed during the waning phase of lahar activity.	Rapid aggradation at the confluence of the Marella- Mapanuepe rivers formed a lahar- dammed lake that probably experienced repeated damming and lake-breakouts.		

IMPLICATIONS FOR MT PINATUBO ERUPTIONS

This study of the Buag eruptive period is useful for anticipating further consequences of the 1991 and future eruptions. The 500-year gap between the Buag eruptive period and the 1991 eruption is one of the shortest in the history of Mt Pinatubo. Repose periods have tended to decrease with time, according to Newhall *et al* (1996), who concluded that the 1991 eruption was the biggest that could be expected from the magma body, but the same authors, however, warned that moderate-size explosive events are still possible. Indeed, if Mt Pinatubo's eruptive style is truly cyclical and always ends when the caldera left by the initial Plinian eruptions is entirely filled by a dome, then the eruptive period that commenced so spectacularly in 1991 is not finished, so we cannot rule out the possibility that dome-building eruptions are yet to come in the coming decades or centuries.

Our study identifies environmental changes that could occur as a consequence of the 1991 and future eruptions. All deltas, including those of the Pampanga and Santo Tomas rivers, subside naturally from isostatic sinking. Due to increasing use of groundwater by growing populations in the Pampanga delta, the rate of subsidence has been increasing in recent decades (Siringan and Rodolfo 2003). However, since the 1991 eruption, lahars have tended to fill these flood plains, temporarily counteracting the subsidence. Since 1991, dikes have been manufactured for all the lahar pathways on Mt Pinatubo to channel volcanic sediments away from the most densely populated areas. These measures have prevented the natural filling of the deltas, thus preventing a natural counteraction to subsidence. The study of the Buag eruptions has shown, however, that volcanoclastic sediment accumulation in shallow coastal environments has reclaimed large tracts of land from the sea. Knowing which areas were covered with lahar deposits of the pre-Buag and Buag eruptive periods may, therefore, help predict the extent of landform transformations that may still take place because of the 1991 and future eruptions. It may also help orient resettlement of flood victims or threatened communities towards safer grounds. Archaeological excavations in Porac have also confirmed the attachment of affected communities to their land, and this should be a major factor to consider in disaster management planning for future eruptions.

Finally, despite the presence of clues in the local cultures, the oral memory of the Buag eruptions had no visible impact in terms of disaster management during the 1991 eruption and subsequent lahar crises. It is, however, very important that the 1991 eruption experience be remembered by the people so that they can prepare properly for the next Mt Pinatubo eruption. Indeed, it has been clearly demonstrated that prior experience of the victims is amongst the most important

factors influencing how they cope with disaster, especially in the case of Mt Pinatubo lahars.

CONCLUSIONS AND OUTLOOK

This multidisciplinary study has compared geological and archaeological data with oral tradition records of the last prehistoric eruption of Mt Pinatubo. The results are important for future risk management because the Buag episode is a good model for future volcanic activity at Pinatubo, even if the magnitude of the eruptions appears to be lessening through time. Cultural artefacts such as tradeware ceramics from both San Marcelino and Porac are consistent with dates of ca 500 ± 50 BP for the last eruption of the Buag period. Because the Chinese were trading in the Mt Pinatubo area, more precise dating may be found through mention in the historical records. The socioeconomic environment at the time of the Buag eruption period still requires detailed study, particularly in terms of the nature and form of connections with China and other Southeast Asian kingdoms.

The present study suggests that victims of volcanic eruptions in ancient times may turn to different alternatives to cope with changes in their immediate environment. Hints from the archaeological and geographical records as well as clues from early written accounts show that people from the eastern and western flanks of Mt Pinatubo did not exploit the creation of large tracts of land in the coastal lowlands. It appears there was a massive redistribution of the population within the plain east of the volcano, whereas the western side of the volcano may have undergone less change. The reasons for such differentiated coping strategies may be diverse and rooted in a large spectrum of factors, as noted in both ancient (Shimoyama 2002) and contemporary cases (Gaillard forthcoming). Our data set on the Buag event is still very sketchy, but we propose that human responses were shaped by the magnitude of the event, the socioeconomic context at the time of the disaster, and the ethnicity of the place.

Our study of the last prehistoric eruptions of Mt Pinatubo should be useful for disaster managers assessing the environmental and socioeconomic consequences of the 1991 and later eruptions. Clear lessons for the future can be learned. Pyroclastic flows may inundate all the river basins draining the volcano. The Mapanuepe River may be dammed and form a lake. Massive lahar flows and subsequent enhanced fluvial sedimentation will infill of shallow coastal embayments and extended the deltaic plains. As these factors are now shown to be typical of volcanic activity from Mt Pinatubo, they require more attention from disaster managers and land-use planners.

The area around Mt Pinatubo was already experiencing extensive trade with China and other foreign kingdoms 500 years ago, and is now one of the leading economic regions of the Philippines. However, the current development plans for the region only take into account the reoccurrence of lahars and ignore potential dome-building leading to further explosive eruptions. The evidence we present indicates that the last Buag eruption may have occurred several centuries after the major plinian eruptions. A dome-building eruption of the magnitudes of the ca 500 BP event at Buag would have serious consequences for modern residents and the Philippines economy.

Our study of the Buag episode shows that the current phase of volcanic activity at Pinatubo is unlikely to be over and that local populations are still at risk; the population is increasing rapidly and the government has concentrated economic interests, such as huge special economic zones, within the 40 km perimeter containing the most devastation in 1991. There is a pressing need to seek more precise timing and delineation of areas affected by the Buag plinian and dome-building eruptions as a model to be used in current risk management. As we have demonstrated here, collaborative studies of volcanic history that integrate findings from geology, geography, archaeology, anthropology, and history are essential to the future of the Philippines and other regions in highly active volcanic regions.

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